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Bimodal EEG-fMRI Neurofeedback for upper motor limb rehabilitation: a pilot study on chronic patients

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Introduction

There is a growing interest in Neurofeedback (NF) or Brain computer interfaces (BCI) for stroke rehabilitation. Generally, NF approaches make use of one imaging technique, and are thus limited in resolution or practicability, depending on the specific imaging modality employed. Integrating EEG and fMRI, two highly complementary imaging modalities, has potential to overcome these limitations [1] and provide a more specific and efficient stimulation of motor areas [2], [3]. In this exploratory work, we tested the feasibility of a multi-session EEG-fMRI NF protocol on four chronic stroke patients, and its potential for upper-limb recovery.

Materials and Methods

Participants and preparation.
Four chronic stroke patients (2 males and 2 females aged between 54 and 76 years) with mild to severe left hemiparesis (Fugl-Meyer score in the range 14-50) were included in the study, after giving their informed consent.

General procedure and study protocol.
After an initial motor assessment, patients underwent a training protocol consisting in two bimodal EEG-fMRI NF sessions interleaved with three unimodal EEG NF sessions and a final motor assessment, within ten days from inclusion. NF run included 8 epochs of rest alternated to periods of training, where the patients were asked to perform kinesthetic Motor Imagery of the affected limb. During NF training, the patients tried to improve their performance with the help of a visual feedback consisting in a ball moving proportionally to the average of ipsilesional EEG and fMRI activity. Data collected in the calibration step that preceded each NF session were processed to estimate an optimal spatial filter for the estimation of the EEG NF score and two regions of interest (ROIs) in the ipsilesional primary motor cortex (M1) and supplementary motor area (SMA) for the calculation of fMRI NF.

Data acquisition.
EEG and fMRI data were simultaneously acquired with a 64-channel MR-compatible EEG solution from Brain Products (Brain Products GmbH, Gilching, Germany) and a 3T Prisma Siemens scanner with a 64-channel head coil. We used the platform in place at the CHU of Rennes [4] that performs EEG and fMRI data streams synchronization and preprocessing, feedback

calculation and visualization. For the unimodal EEG-sessions an 8 channels Mensia Modulo EEG solution was used (MENSIA TECHNOLOGIES, https://www.mensia.com/). The EEG NF score was calculated as the event related desynchronization of filtered EEG data in the 8-30 Hz band and updated every 250 ms. The fMRI NF feature was proportional to the percent signal change in the SMA and M1 ROIs with respect to a background region and was updated every second.

Data analysis.

Clinical outcomes were assessed by a certified therapist using the Fugl-Meyer upper extremity test (FMA-UE) and the Motor Activity Log (MAL). Pre-processing and a first-level general linear model analysis was performed on fMRI data. The activations maps were Family-Wise error corrected ($p < 0.05$). Similarly, for the EEG analysis data were first pre-processed offline with a semi-automatic artifact rejection procedure implemented in Brain Products Analyzer, data were then filtered between 8 and 30 Hz and ERD activations during both unimodal and bimodal NF estimated.

Results and Conclusions

Participants were motivated to test NF training and satisfied with the visual metaphor and how it translated their motor imagery task, as assessed by a questionnaire at the end of the training protocol. All the patients were able to upregulate their activity during NF training with respect to rest in the ipsilesional SMA and M1 ($p<0.004$, Wilcoxon test). Three over four patients showed a significant increase in ipsilesional M1 activation at the end of the protocol with respect to the first training session. Of these three individuals, two exhibited an increase in FMA-UE score (of +3 and +6 points respectively).

Preliminary results from this pilot study showed feasibility of multisession bimodal EEG-fMRI in chronic stroke patients and indicated the potential of this training protocol for upper-limb recovery after stroke. This exploratory work was also useful to identify important aspects and to define inclusion criteria of the larger cohort randomized control study we are performing at the moment.

References

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